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(56) Documents Cited
GB 2081387 A GB 2061395 A GB 1580805 A
WO 86/06139 A1 WO 84/00583 A1 US 3989951 A

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(54) Extracting energy from waves

(57) A method and an apparatus for generating electricity from wave energy which comprises a plurality of juxtaposed chambers (10) located along a gradient below sea level. Each chamber (10) is connected to its next adjacent chamber by one-way valve means (12) and bellows or diaphragm members (11) are located above said chambers (10), one for each chamber (10). Wave action, acting upon such members (11), provides a pressure differential between the two most remote chambers (10) which is utilised for generating electricity. A plurality of rows of chambers may be used with interconnections therebetween (figure 4). The chambers may be made from reinforced concrete which may be moulded in situ.

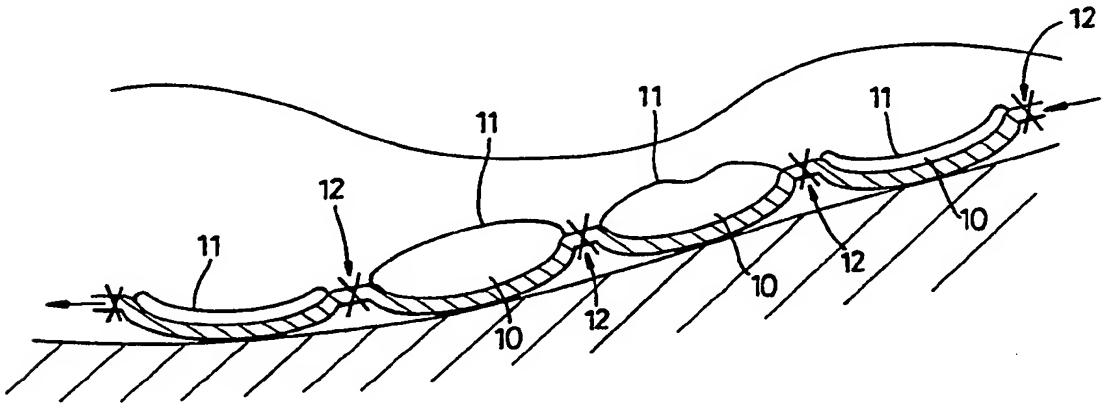

Fig. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

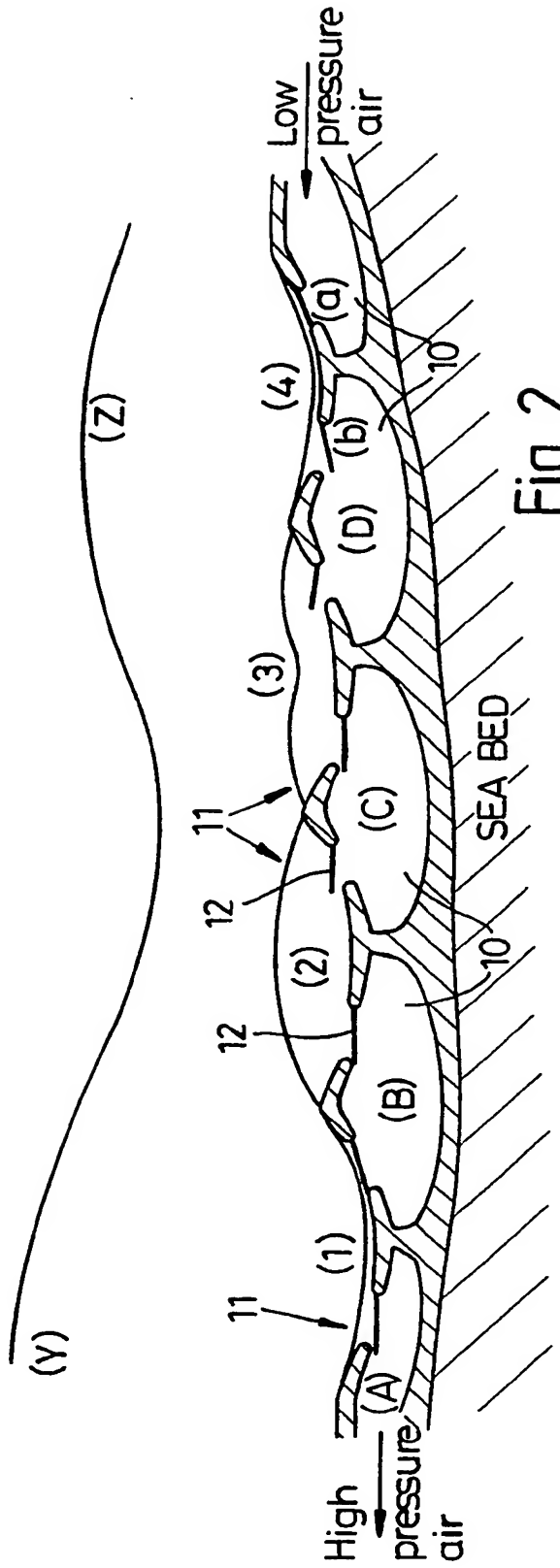

Fig. 2

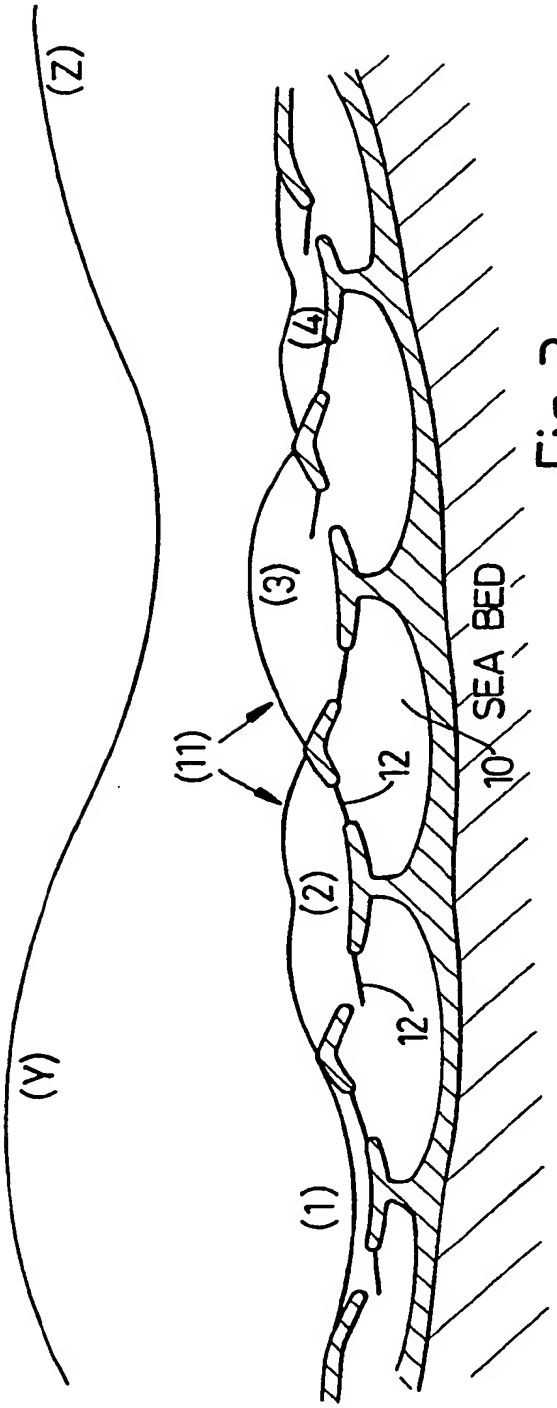

Fig. 3

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IMPROVEMENTS IN AND RELATING TO THE GENERATION OF ELECTRICITY

The invention relates to the generation of electricity and more particularly to methods and apparatus for the generation of electricity utilising wave energy.

Many schemes have been proposed for utilising wave energy for generating electricity, some of which are disclosed in report ETSU-R-72 published by The Department of Trade & Industry in 1992 and entitled "A Review of Wave Energy". The majority of the known arrangements are located at or above sea level, so being environmentally unfriendly and being subject to damage by extreme weather conditions, and all are extremely inefficient in their conversion of wave energy.

It is an object of the invention to obviate or mitigate the above disadvantages.

According to one aspect of the invention there is provided a method of generating electricity from wave energy which comprises, locating a plurality of juxtaposed chambers along gradient below sea level, connecting each chamber to its next adjacent chamber by a one-way valve and locating bellows or diaphragm members one above each of said chambers to enclose a volume therewith, whereby wave action, acting upon such members, provides a pressure differential between the two most remote chambers which is utilised for generating electricity.

According to a further aspect of the invention there is provided a method of generating electricity from wave energy which comprises, locating a plurality of juxtaposed chambers along a gradient below sea level, connecting each chamber to its next adjacent chamber by respective one-way valves and locating

Each bellows member may comprise a sheet of strong flexible synthectic plastics material and may be in the order of five meters in diameter.

The juxtaposed chambers may be formed in situ from reinforced concrete or may be provide as preformed sections, and located at or near the sea bed.

The foregoing and further features of the invention may be more readily understood from the following description of some preferred embodiments thereof, by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 is a schematic side sectional view of an apparatus of one embodiment of the invention;

Fig. 2 is a schematic side sectional view of an alternative apparatus in a first condition relative to the first wave position;

Fig. 3 is a view similar to Fig. 2 in a second condition relative to a second wave position, and

Fig. 4 is a plan view of a typical apparatus as shown in Figs. 1, 2 and 3.

Referring now to Fig. 1 of the drawings there is shown schematically an apparatus for utilising wave energy for generating electricity. A plurality of chambers 10 each having an upper surface formed by a diaphragm or bellows 11 are juxtaposed with one-way valves 12 therebetween. The chambers 10 are located at or near the sea bed and the operation of this apparatus is similar to that described in detail in respect of the embodiment of Figs. 2 and 3.

Waves rolling in upon a coast exert varying pressures on points on the sea bed determined by alternate crests and troughs as they pass. Thus if a shallow concrete dish, over which is sealed a strong flexible plastic sheet, is placed on the sea bed and if that dish and sheet contain air, the pressure of that

shown) while bellows (4) is fed with air from a low pressure reservoir (not shown), whose pressure is appropriately controlled as mentioned above.

It will be noted that in the above arrangements, where the non-return air valves are installed to pass air to lower levels only, the system will function no matter from which direction the waves approach. The wave length or frequency does not have any relevance to the positioning of the bellows or their size, provided that the wave length is more than twice the bellow's diameter.

Each bellows operates as an independent unit no matter from which direction waves approach or what their frequency is. Even if the crests of the waves lie parallel to the line of the bellows in Figs 2 & 3 the pumping action will function normally, the only difference being that a wave crest will pass over all four bellows simultaneously, forcing the air into all four chambers at the same time; when the next trough passes all four bellows will refill together.

The foregoing is diagrammatic and simplified in order to demonstrate the principle of the bellows action. In fact a bellows battery containing a large number of bellows would be used and a plan view of such a battery is shown at Fig 4. In this arrangement, although each bellows remains individual, the air chambers are joined together horizontally to form air ducts along the length of the battery and running along contours of the sea bed. Thus a constant pressure over the entire length of the duct would be maintained. It is envisaged that the seaward duct would be about 10 metres lower than the in-shore duct, giving a constant pressure difference between a high and a low pressure air reservoir. The actual pressures would vary with the state of the tide, requiring the control of the

contour to 38% of its original energy in deep water. This 38% is further reduced to 32% by the depth of the sea bed (0.85 for a 11.5 second period). However, if the rolling motion does reverse, the Bellows Battery could be sited in much deeper water, say in a depth of 42m at which depth the Bristol Cylinder (described in ETSU-R-72) would be sited.

Compared below is the energy collectable by the presently proposed bellows system and the Bristol Cylinder (which would seem to be one of the more favoured known devices):-

(a) Bristol cylinder (moored at 42m, centre of cylinder at 14m)

Wave energy in deep water	100%
Reduced at 42m by bottom drag to	58%
Reduced by directionality (35%) to	37.7%
Reduced by mixed frequency (50%) to	18.85%
Reduced by depth below surface (20%) to	15%

(b) Bellows System (sited around 10m. NO reversal of rolling water)

Wave energy in deep water	100%
Reduced at 10m by bottom drag to	38%
Reduced by directionality NIL	38%
Reduced by mixed frequency NIL	38%
Reduced by depth below surface (15%) to	32%

(c) Bellows System (sited around 42m. Reversal of rolling motion present)

Wave energy in deep water	100%
Reduced at 42m by bottom drag to	58%
Reduced by directionality NIL	58%
Reduced by mixed frequency NIL	58%
Reduced by depth below surface NIL	58%

Hence the bellows system would appear to be over twice as efficient as the Bristol Cylinder if no reversal of rolling motion occurs (32% as against 15%),

(g) It appears to be considerably more efficient in collecting wave energy than the Bristol Cylinder, which is one the more favoured known devices.

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6. A method as claimed in any preceding claim wherein the juxtaposed chambers are formed of reinforced concrete moulded in situ.

7. A method as claimed in any one of claims 1 to 5 inclusive wherein the juxtaposed chambers are formed of reinforced concrete and are provided as preformed sections.

8. A method as claimed in claim 3 or any claim appendent thereto wherein air is introduced into the chamber(s) nearest the beach or shoreline at low pressure and exhausted at higher pressure at the remote chamber(s).

9. A method as claimed in claim 8 wherein the compressed air is utilised to raise water to a high level water reservoir and then utilised for the generation of electricity by conventional hydroelectric means.

10. An apparatus for generating electricity from wave energy which comprises a plurality of juxtaposed chambers located along a gradient below sea level, each chamber being connected to its adjacent chamber by one-way valve means, and bellows or diaphragm members located above said chambers, one for each chamber, whereby wave action, acting upon such members, provides a pressure differential between the two most remote chambers which is utilised for generating electricity, in use.

11. An apparatus as claimed in claim 10 wherein each bellows member comprises a sheet of flexible synthetic plastics material.

12. An apparatus as claimed in claim 10 or 11 wherein each bellows member is in the order of five meters in diameter.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report) -13-

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Relevant Technical Fields

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Search Examiner
C B VOSPER

Date of completion of Search
4 NOVEMBER 1994

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASE WPI

Documents considered relevant following a search in respect of Claims :-
1 TO 16

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	GB 2081387 A	(VICKERS) whole document - shows flexible chambers interconnected by one-way valves but not located along a gradient below sea level	1, 2, 10
A	GB 2061395 A	(FRENCH) whole document - shows flexible chambers interconnected by one-way valves but not located along a gradient below sea level US Equivalent = 4375151	1, 2, 10
A	GB 1580805	(FRENCH) whole document - shows flexible chambers interconnected by non-return valves but not located along a gradient below sea level US Equivalent = 4164383	1, 2, 10
A	WO 86/06139	(HYDRO) Figures 3B to E, 4B and 9 in particular - show flexible chambers located along a gradient but not below sea level so as to be operated by waves	1, 2, 10
A	WO 84/00583	(HERTZ) whole document - shows flexible chambers interconnected by one-way valves but not located along a gradient belong sea level	1, 2, 10
A	US 3989951	(LESSTER/WESTINGHOUSE) whole document - shows flexible chambers connected by one-way valves but not located below sea level along a gradient	1, 2, 10

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).